# Forward Tracking at eRHIC

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# Forward protons in the measurements for EIC

- Diffractive proton in exclusive Deeply Virtual Compton Scattering (DVCS) process: (S. Fazio, yesterday)
- Spectator protons in polarized e+$^3$He in inclusive DIS for polarized neutron structure function $g_1^n(x,Q^2)$ and flavor separation in semi-inclusive DIS: (Riken He-3 workshop 9/28/2012 )
- Large-$x_F$ protons: separating $k_T$ vs QCD: (M. Baker, EIC TF Meeting 9/13/2012)
- ...

# Forward protons

- Diffractive proton tagging/tracking near beam:
  $\theta \sim O(\text{mrad})$, $0 < |t| <$ a few $\text{GeV}^2$ at 250 GeV beam
- high-t acceptance mainly limited by magnet aperture
- low-t acceptance limited by beam envelop (~10σ) and optics
- uncertainty in t
  - beam angular divergence for mainly small t
  - transport, field
  - detector alignment relative to the beam
  - uncertainties in collision vertex (x,y,z)
  - ~<5% resolution (mainly scale error) in t of elastic events (RP at STAR)

# Detector

- Movable insertions into beam vacuum: Roman Pot (RP)
- Current simulation based on STAR RP
  - Proven technology: Silicon100μm strip
  - 4-sided (2 Up/Down 2 Left/Right) active area of 10cmx7cm (flexible)
  - RP at 20, 22m for eRHIC
  - High efficiency, good resolution
- RP Phase II at STAR (2014?)
  - more eRHIC-like environment
  - wide t-range requiring full reconstruction
  - exposed to high-luminosity, more background

# Simulator:Hector

- "A fast simulator for particle transport through beam line"
  - J. de Favereau, X. Rouby and K. Piotrzkowski  arXiv:0707.1198
  - https://cp3.irmp.ucl.ac.be/projects/cp3admin/wiki/UsersPage/Physics/Hector
- Current version 1.5.2 (2009)
- ROOT based
- Optics input compatible with the simulation package used by machine design
- currently Runs on RCF machines
- used for the various RHIC/STAR optics simulations and data analysis
- Limitation
  - High-order magnets, rotations...

# Combining of beam transport + forward detector detectors with main detectors

- Delphes (arXiv:0903.2225) https://cp3.irmp.ucl.ac.be/projects/delphes

**A framework for fast simulation of a generic collider experiment**

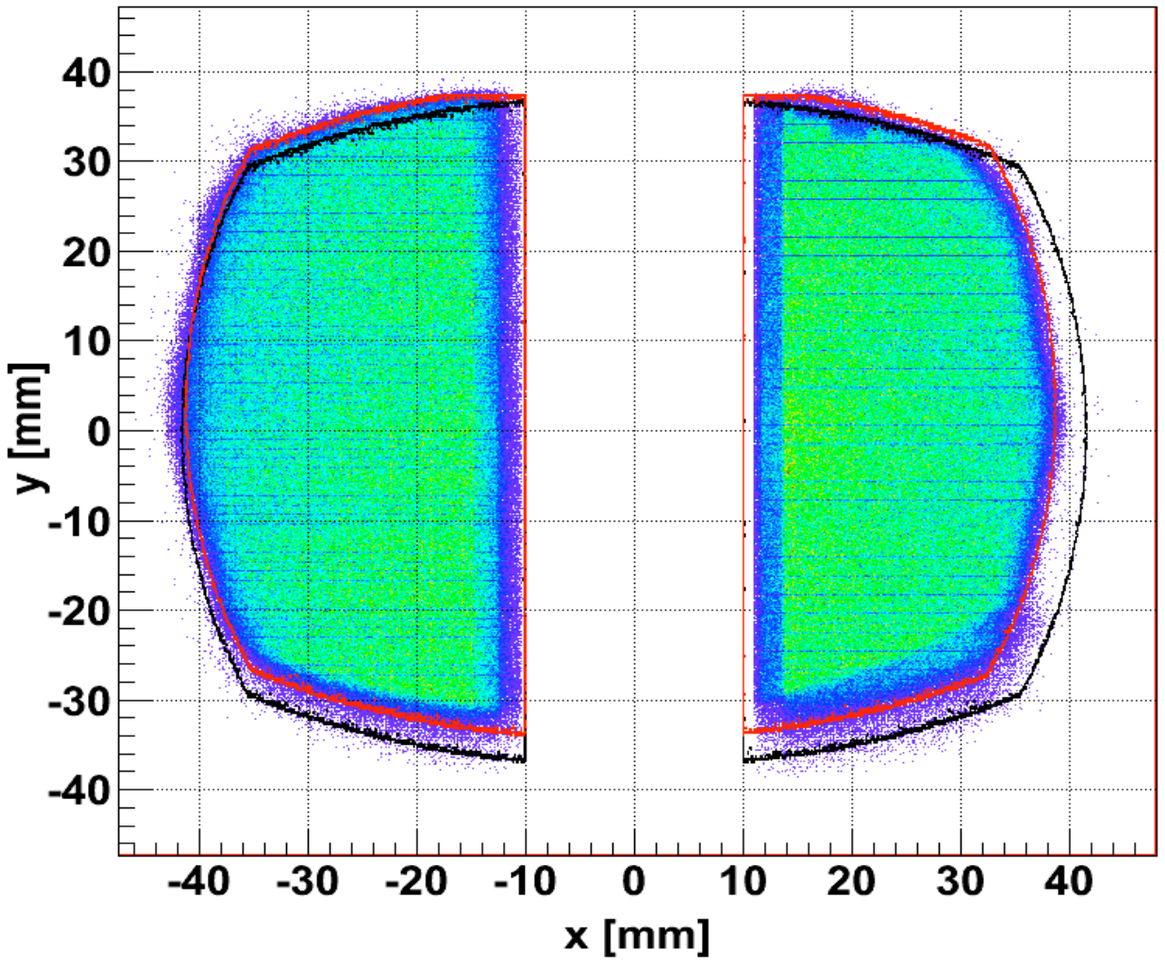
Delphes is a C++ framework, performing a fast multipurpose detector response simulation. The simulation includes a tracking system, embedded into a magnetic field, calorimeters and a muon system, and possible very forward detectors arranged along the beamline. The framework is interfaced to standard file formats (e.g. Les Houches Event File or HepMC) and outputs observables such as isolated leptons, missing transverse energy and collection of jets which can be used for dedicated analyses. The simulation of the detector response takes into account the effect of magnetic field, the granularity of the calorimeters and subdetector resolutions. A simplified preselection can also be applied on processed events for trigger emulation. Detection of very forward scattered particles relies on the transport in beamlines with the HECTOR software. Finally, the FROG 2D/3D event display is used for visualisation of the collision final states.

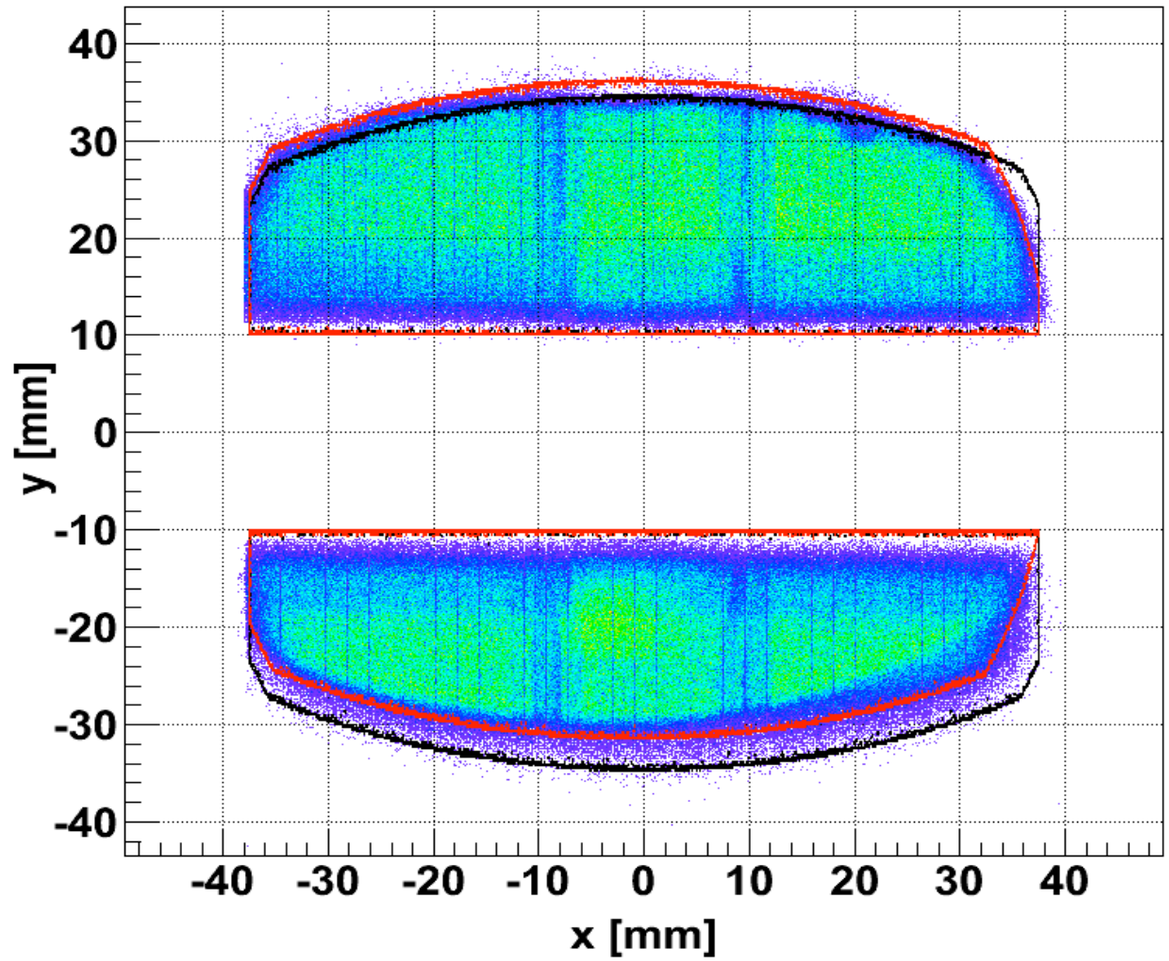
  - "A Framework for fast simulation of a generic collider experiment"
  - Detector response+Trigger
  - Hector + Fast simulator for main detectors
- Hector (ROOT/C++ based) can be combined with simulation packages

# Other Beam Transport simulators

- MAD/Mad-X
  - "standard" comprehensive transport simulation
  - developed/maintained by CERN Accelerator Group
  - used by RHIC/eRHIC machine design
  - non-trivial to combine with other analysis frame
- Geant4
  - full detector simulation
  - needed for response, background estimate
  - being implemented for RHIC/STAR

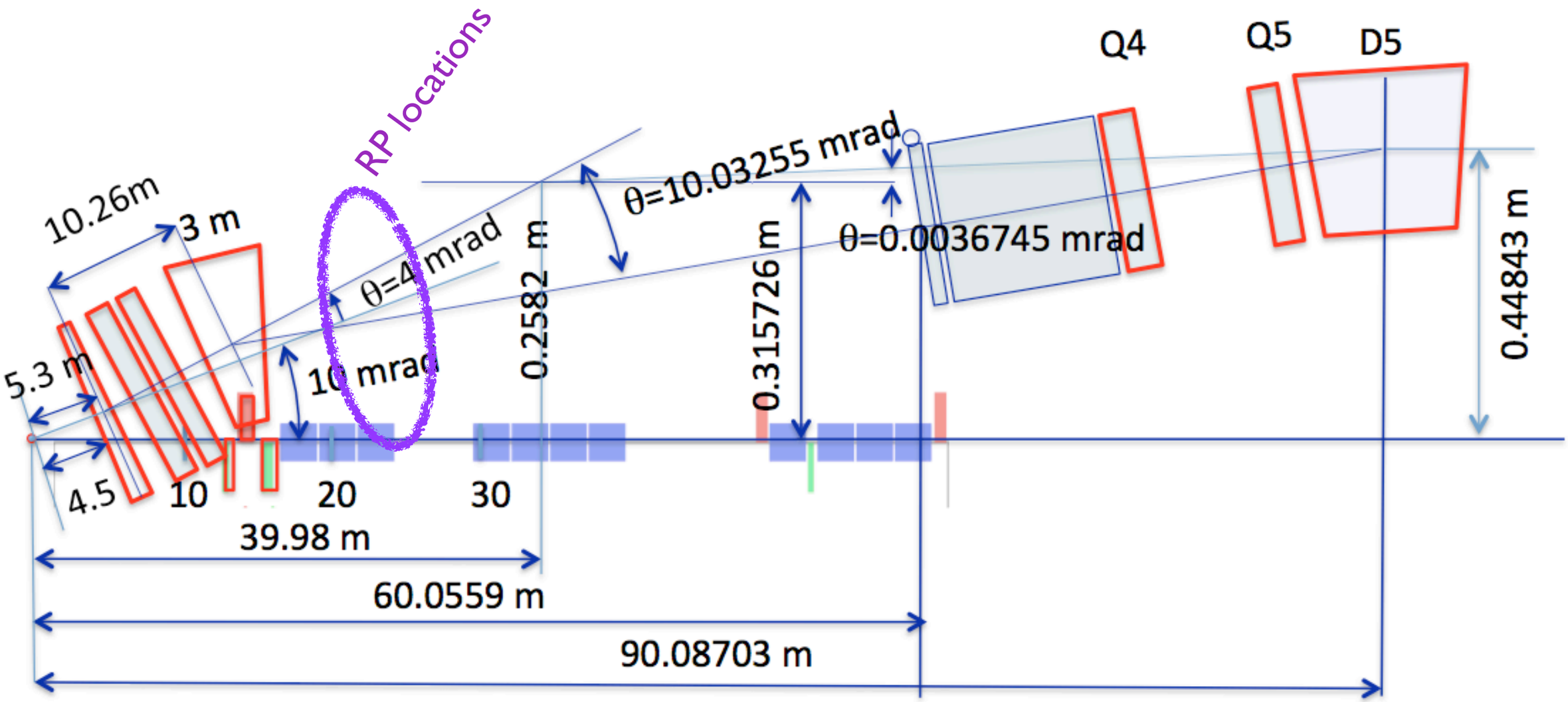
# Example of Hector simulation: comparing with RHIC/STAR data



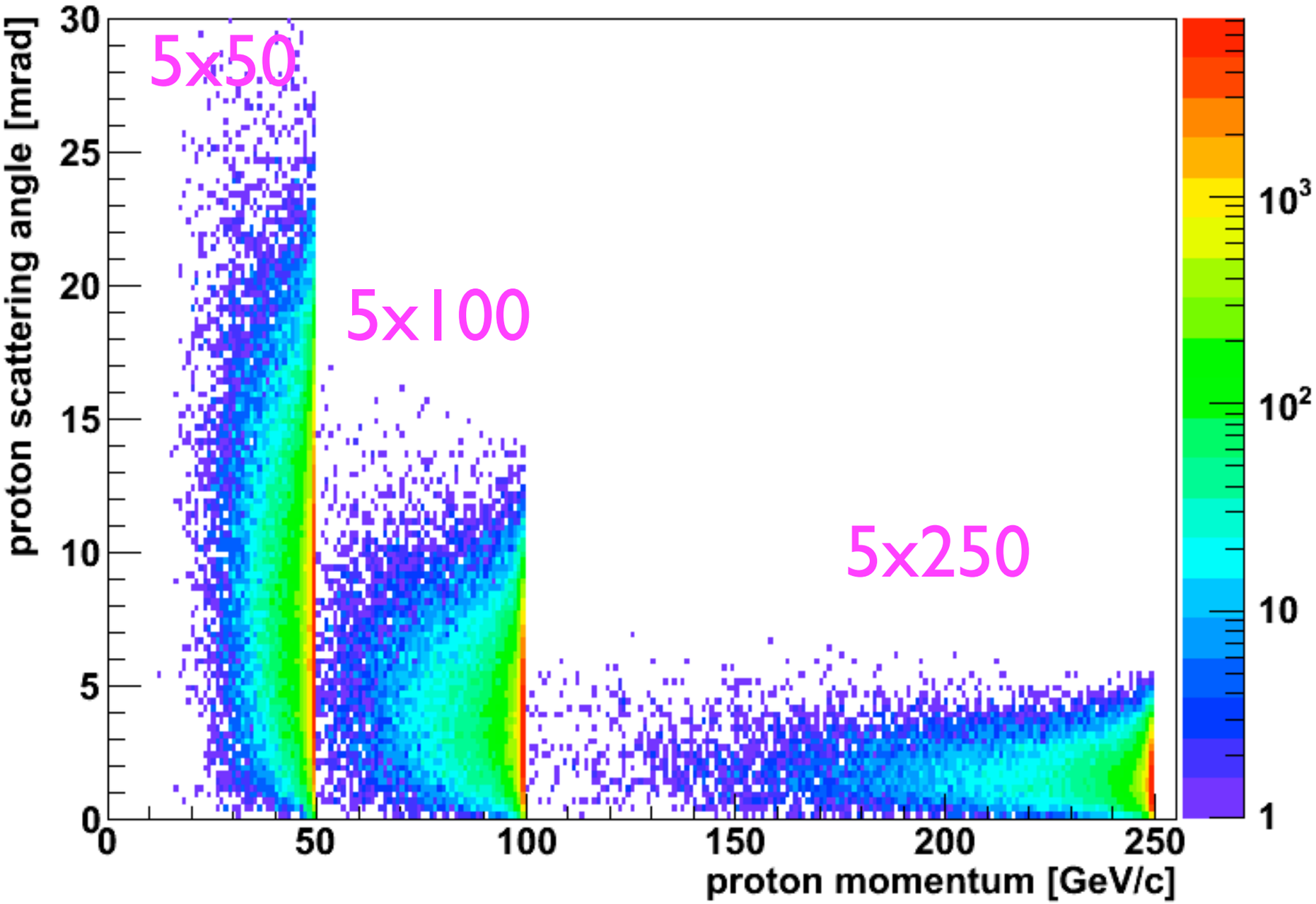

- Data: elastic proton hit distribution in the RPs at 55m and 58m from IR
  - Red: Hector simulation with tuning (geometry, field)
  - Blank: Hector simulation with nominal transport

# eRHIC IP configuration

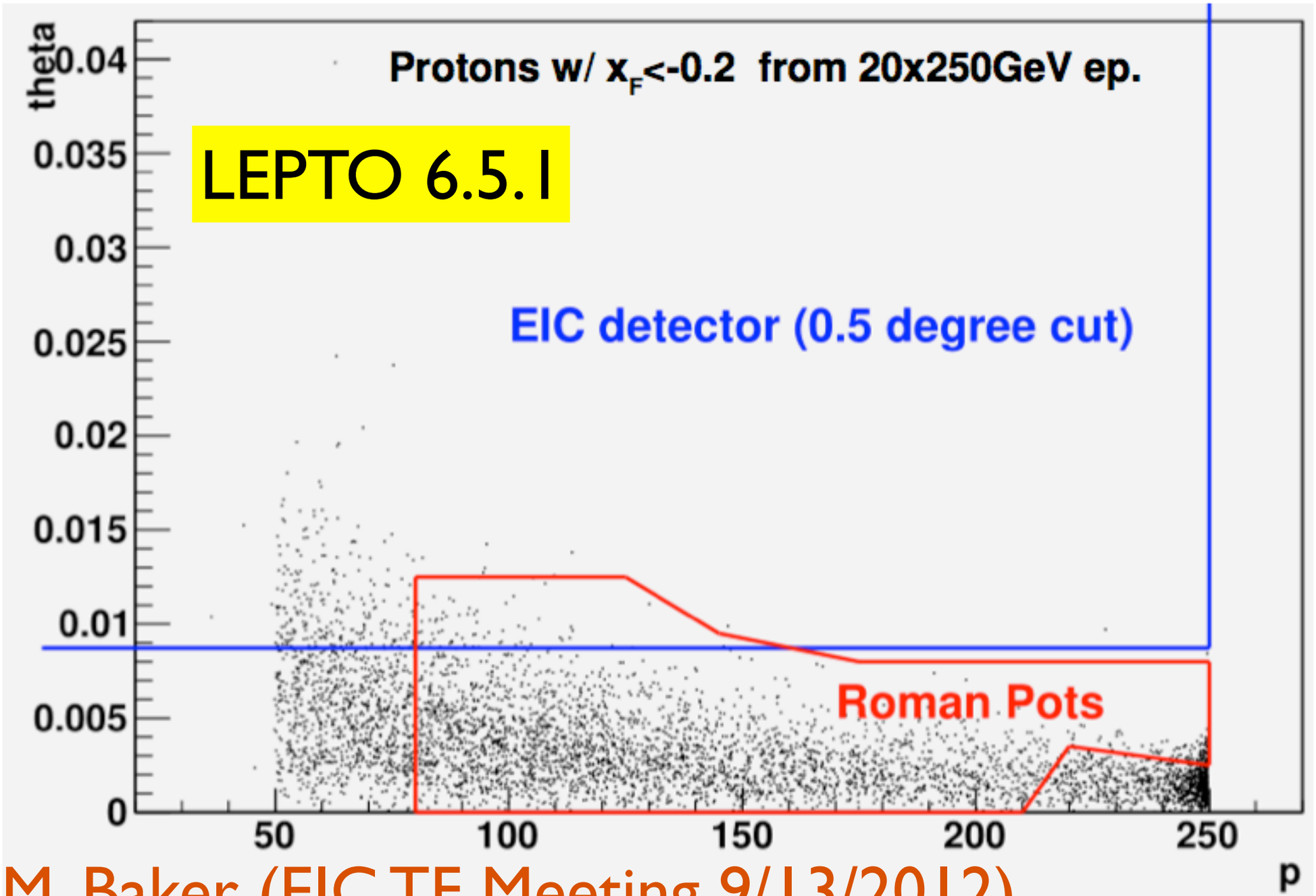



June 2011 D. Trbojevic

# Where the forward proton scattering angle vs momentum from DVCS (MILOU)

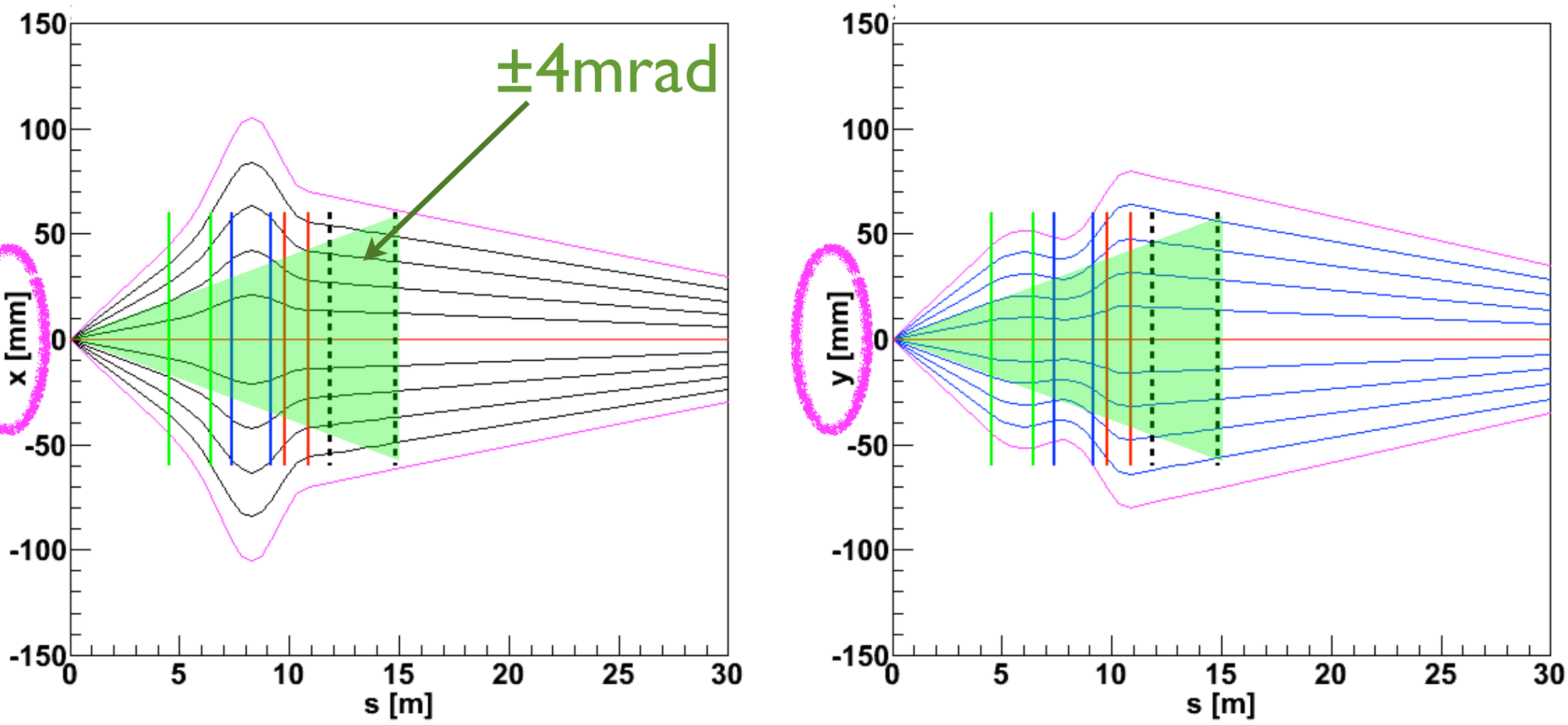


# High-$x_F$ protons for $k_T$ study



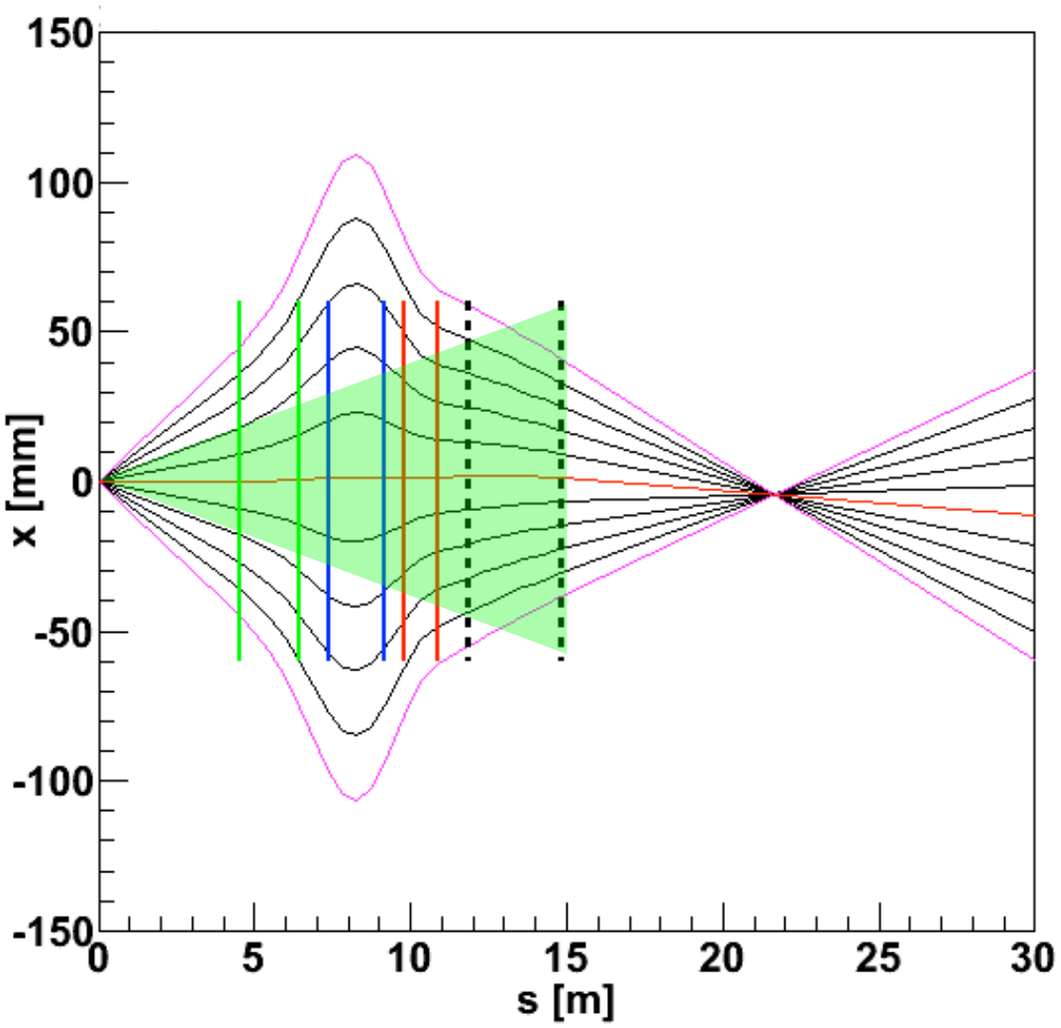

M. Baker (EIC TF Meeting 9/13/2012)

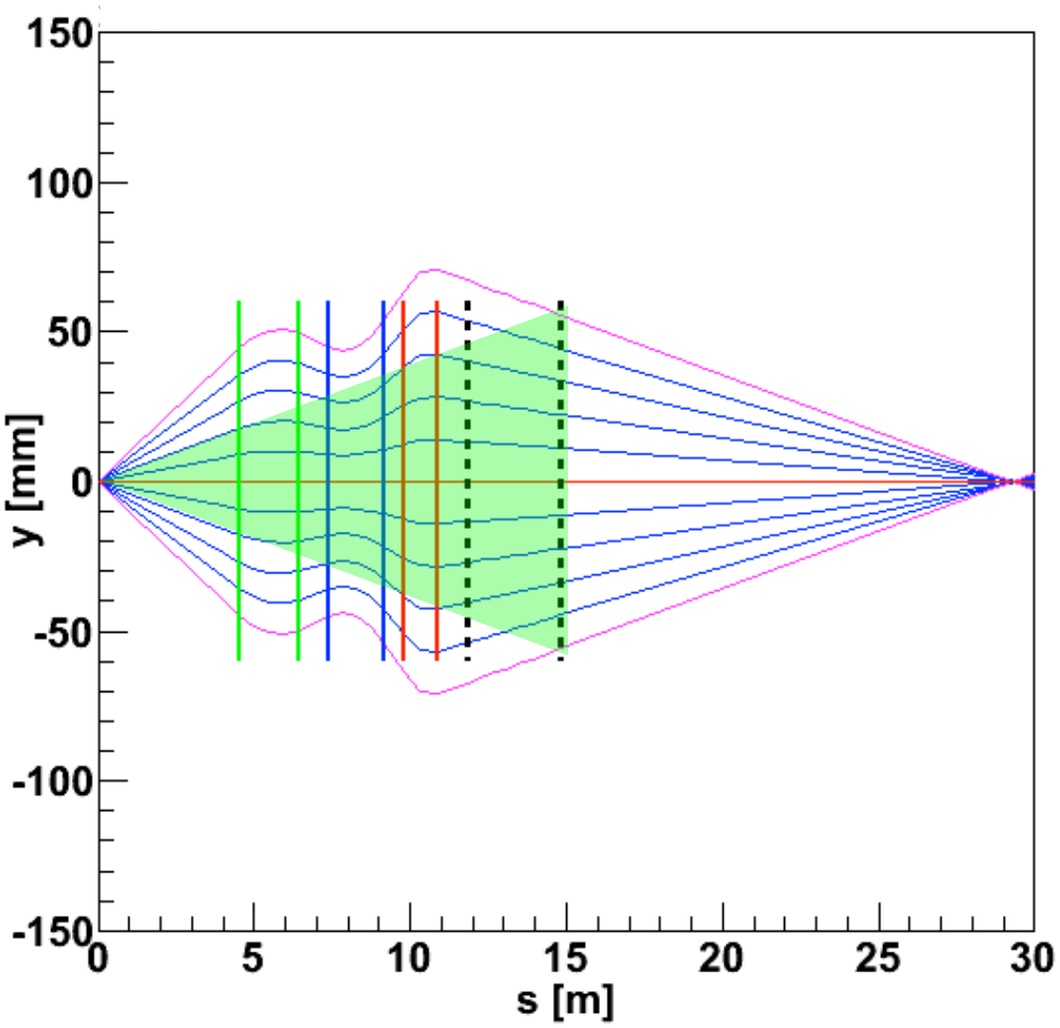
# proton with nominal momentum



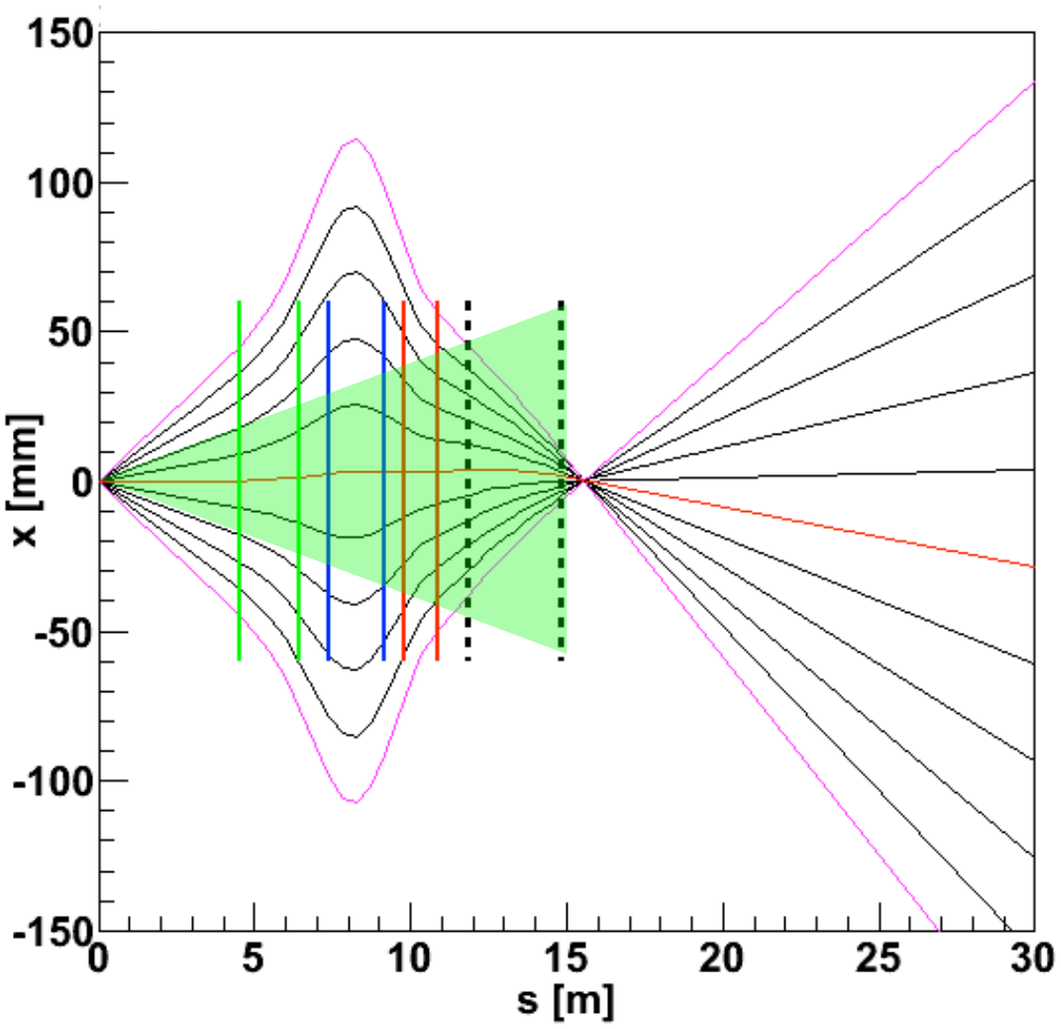

- shown protons with nominal momentum in ±10 mrad
  - 250 GeV proton: at 6 mrad: 2.25 $GeV^2$, at 10 mrad: 6.25 $GeV^2$
  - 100 GeV proton: at 6 mrad: 0.36 $GeV^2$, at 10 mrad: 1.0 $GeV^2$

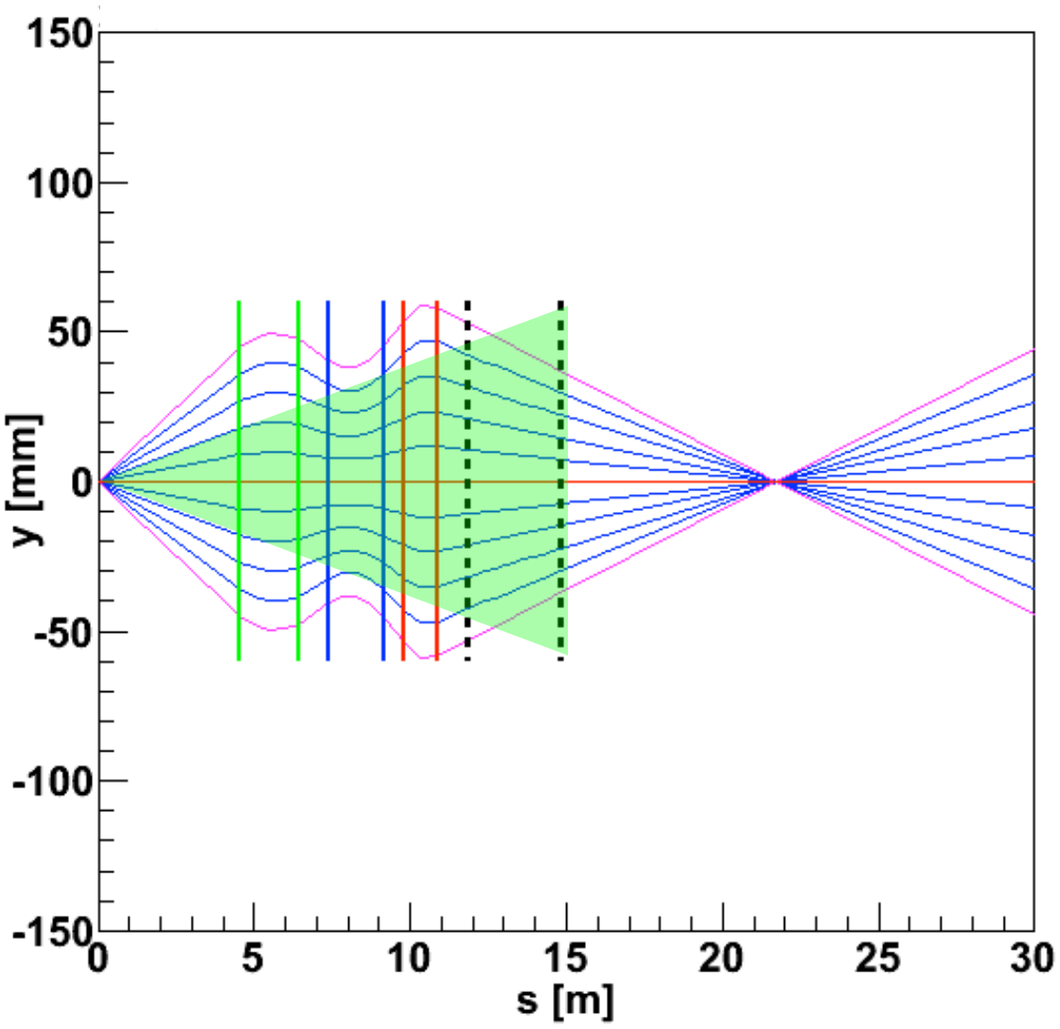
# proton with 10% momentum loss
# (~large t in DVCS)



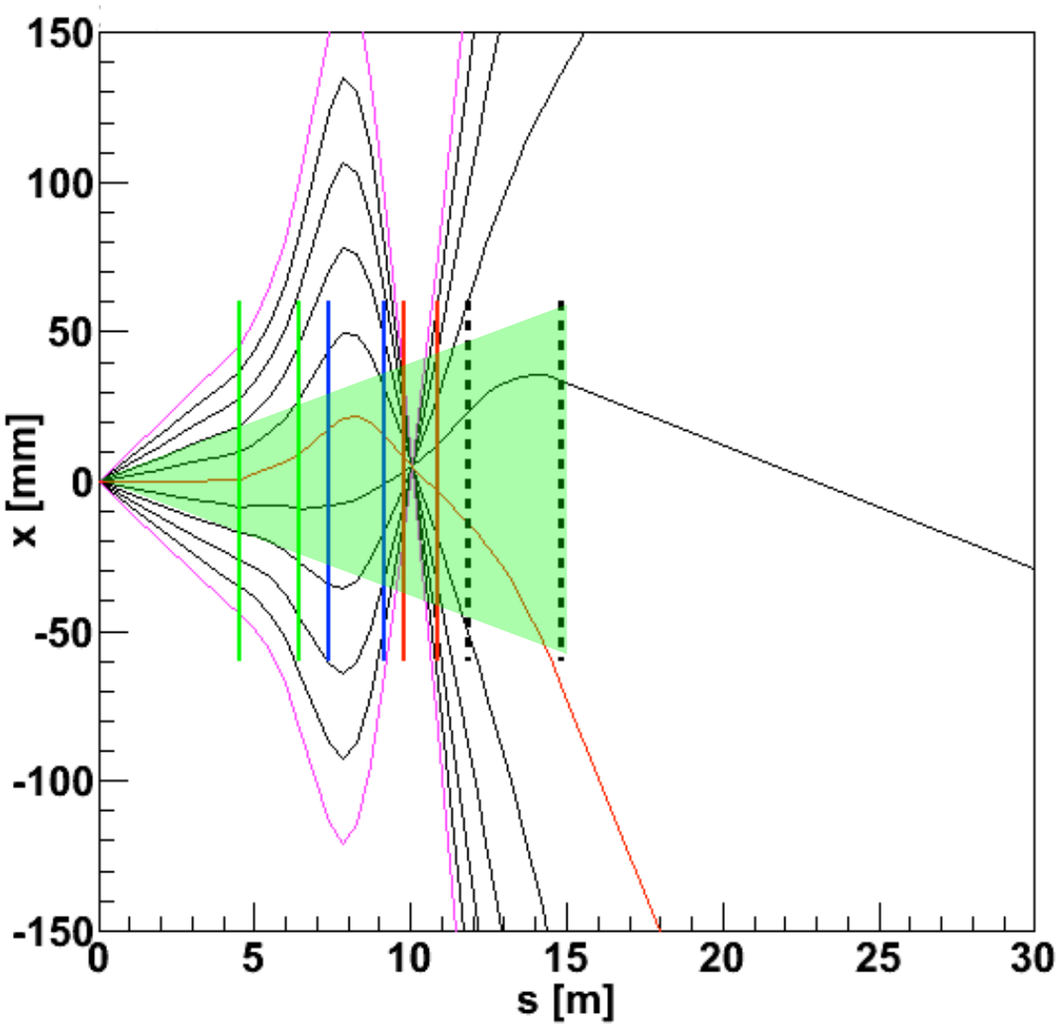



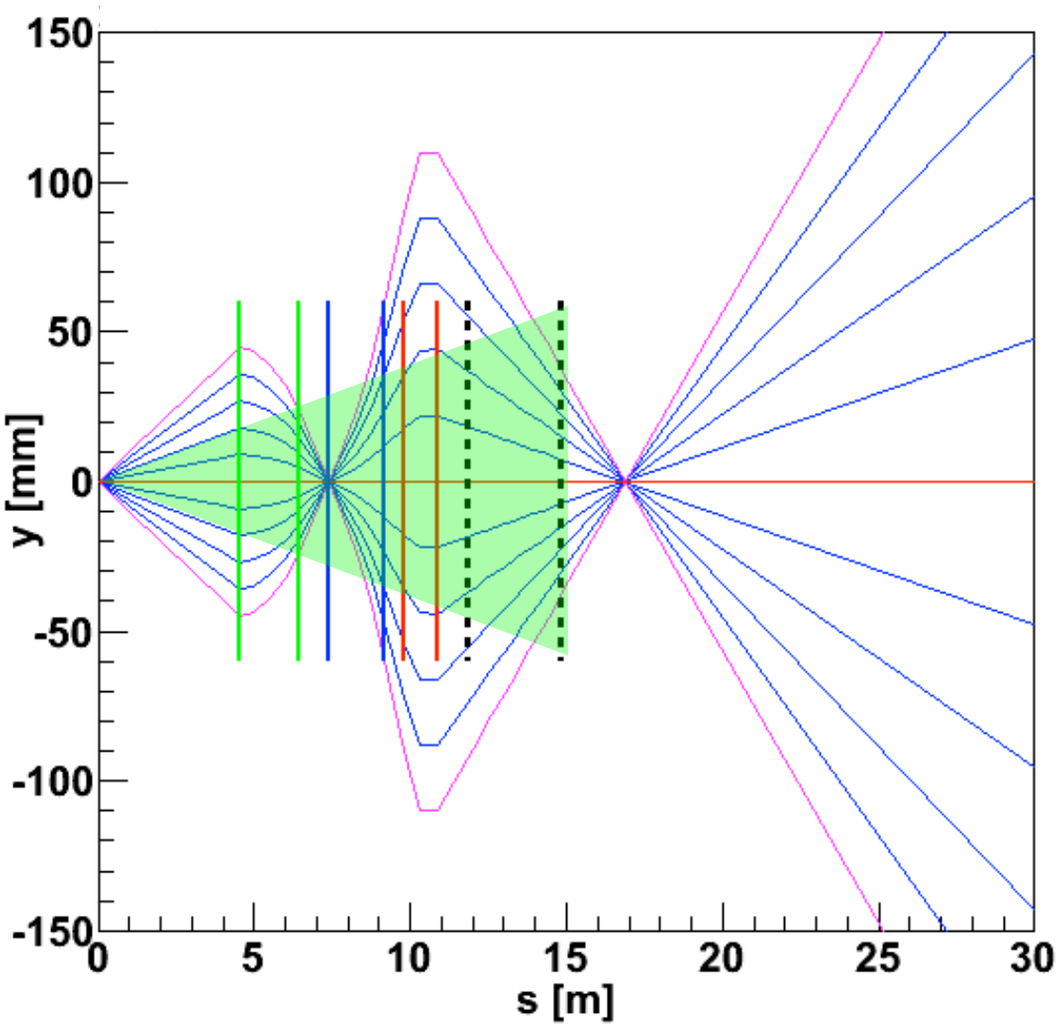
# proton with 20% momentum loss (~lower limit in DVCS)



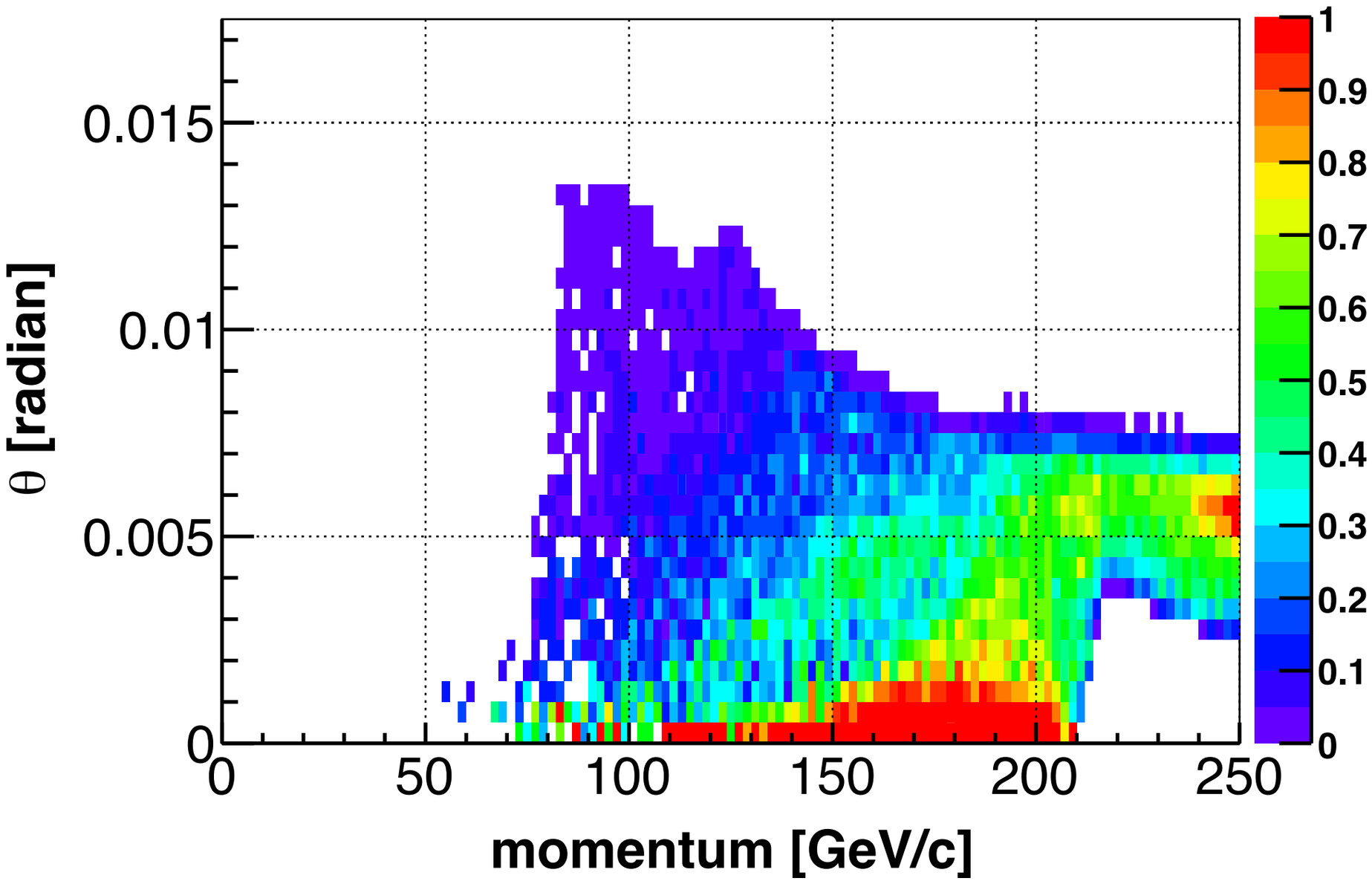



# proton with 60% momentum loss
# (spectator protons from Au in e+Au)

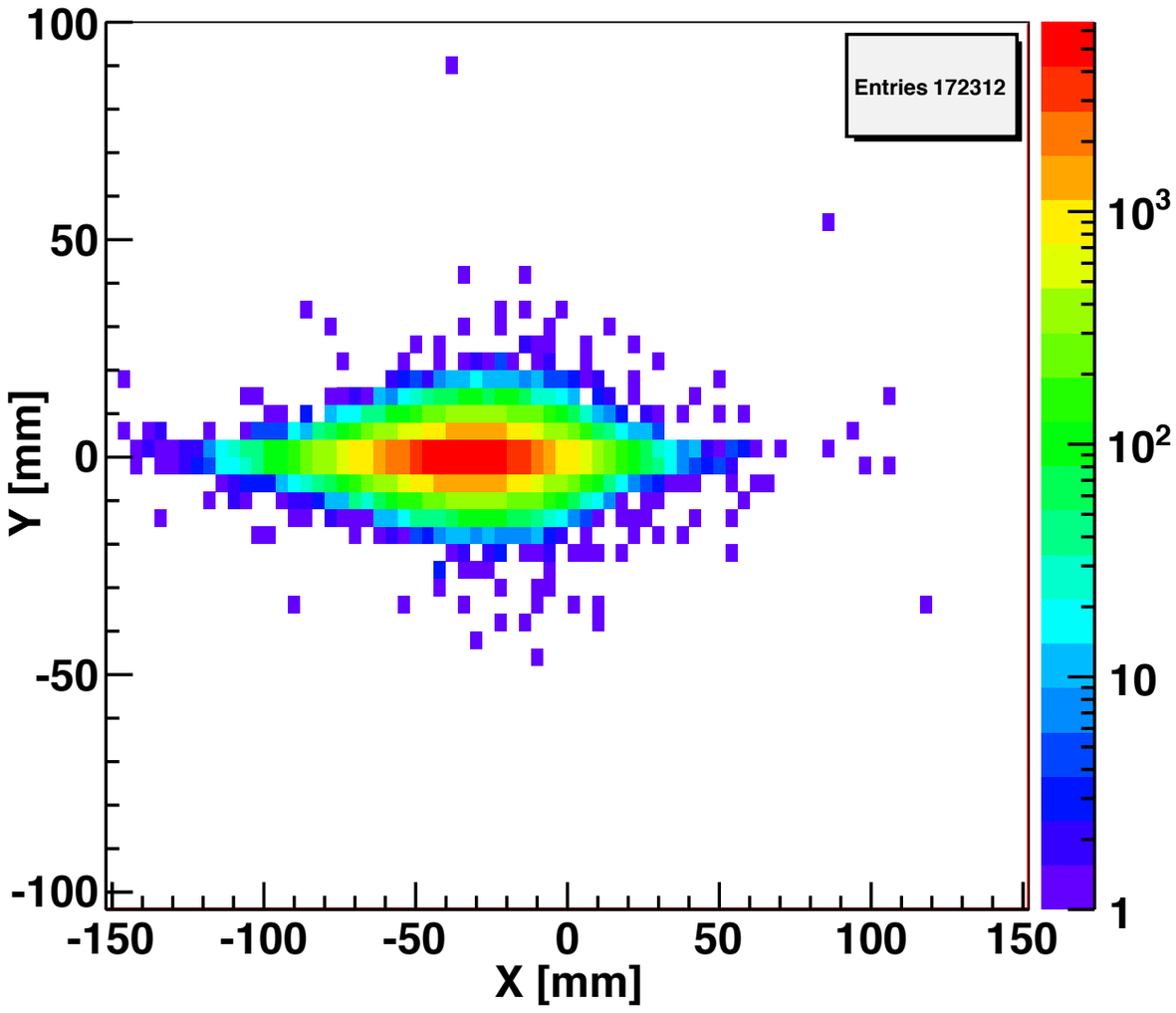


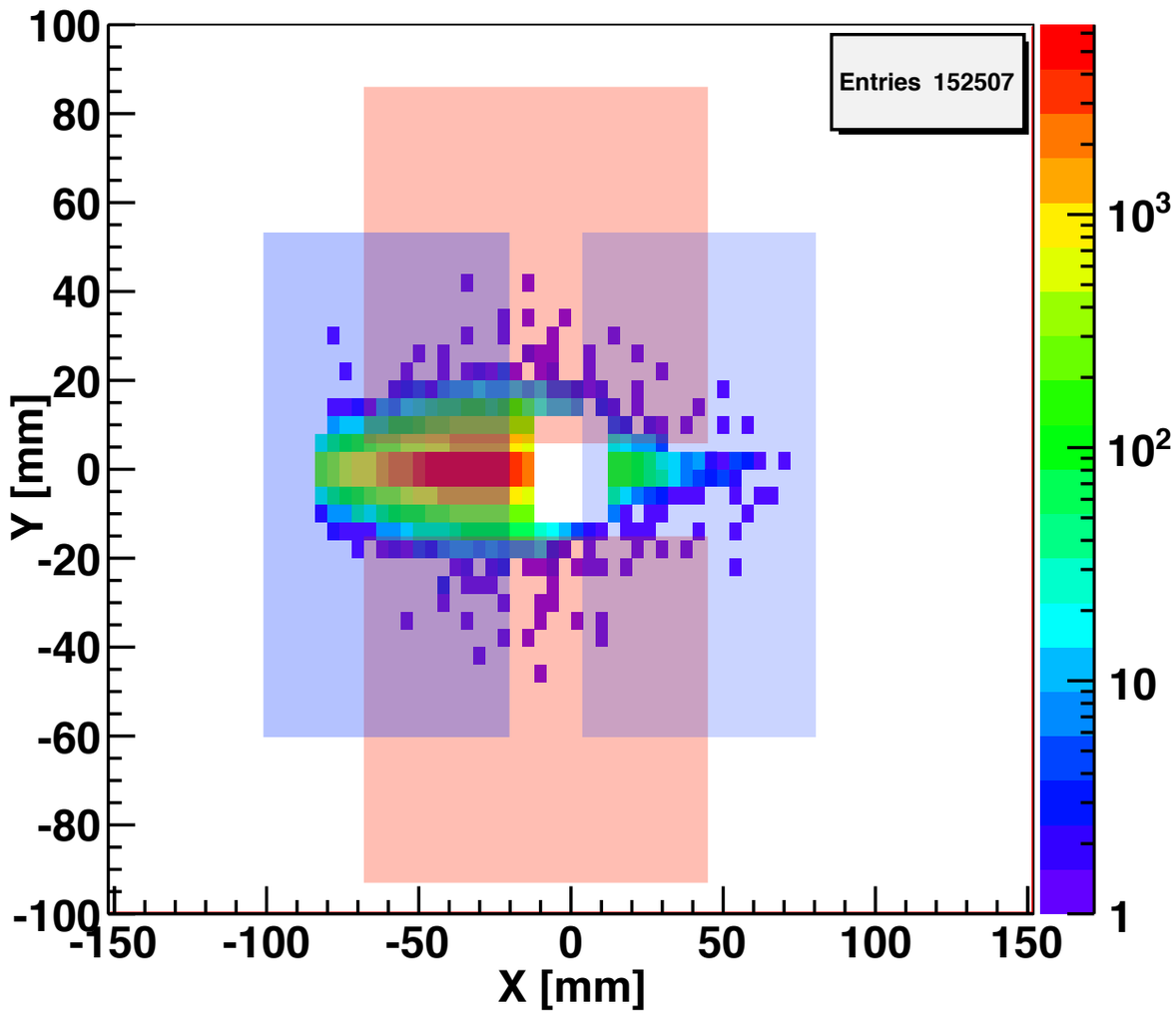



# Proton acceptance in RPs at 20,22m



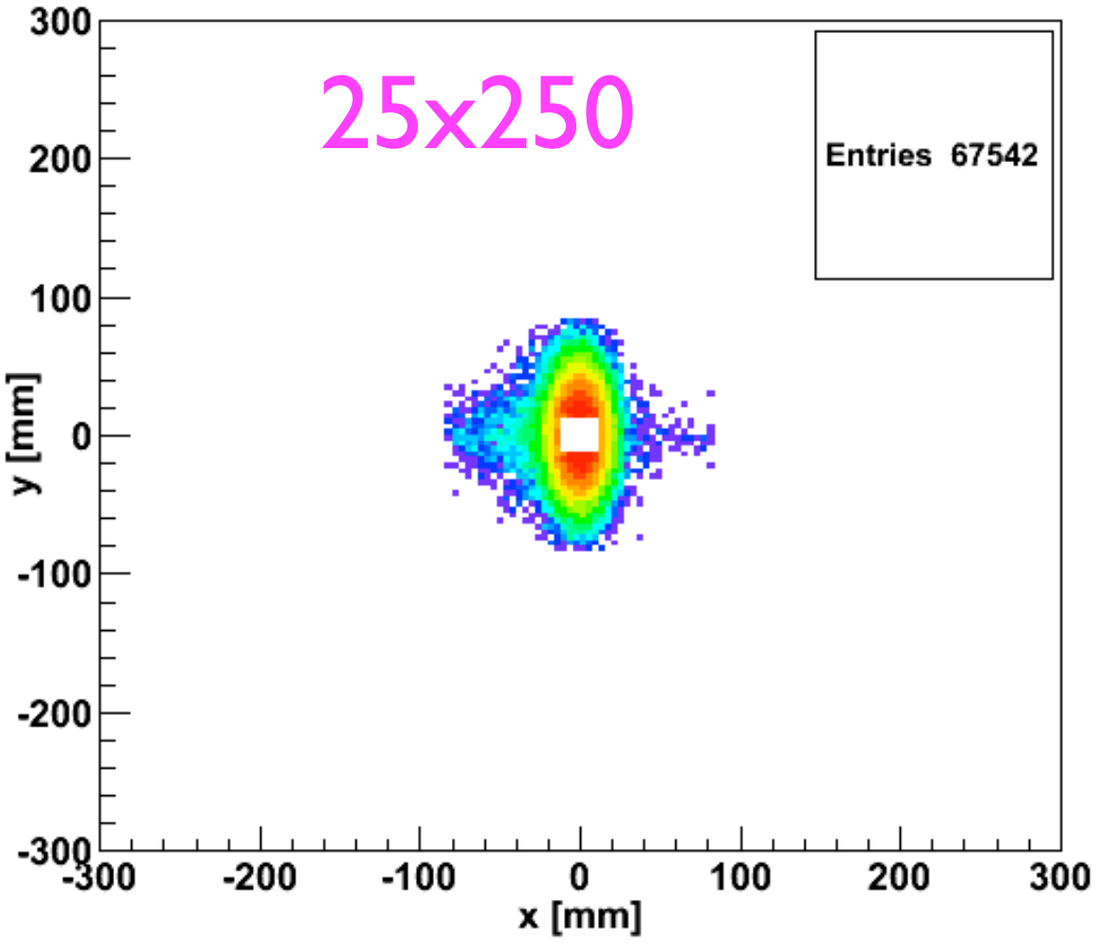
# Example: spectator proton from $^3$He

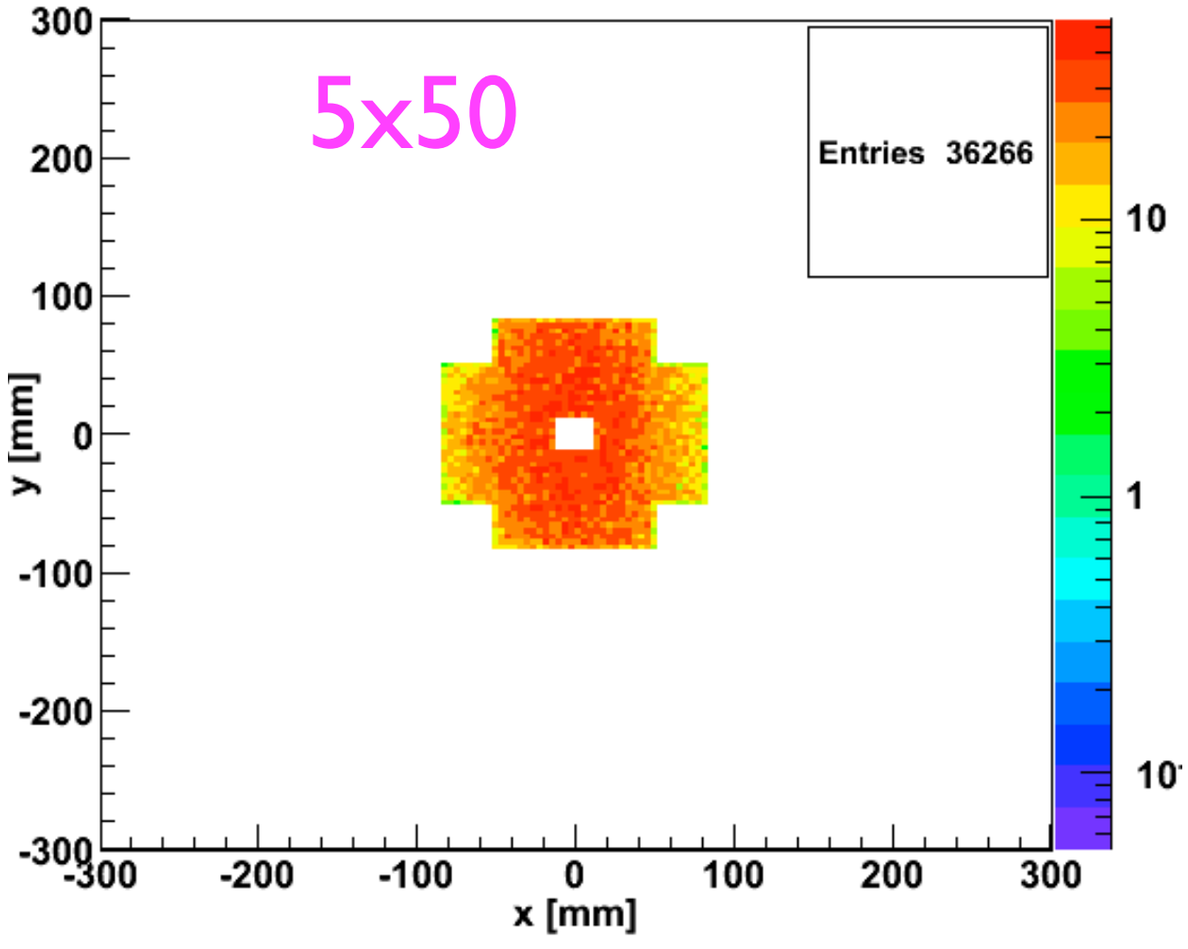



- Spectator proton acceptance in RP ~ 90% with the assumed design

# Example: protons from DVCS in RP



# Forward tracking at eRHIC: Simulation Forward

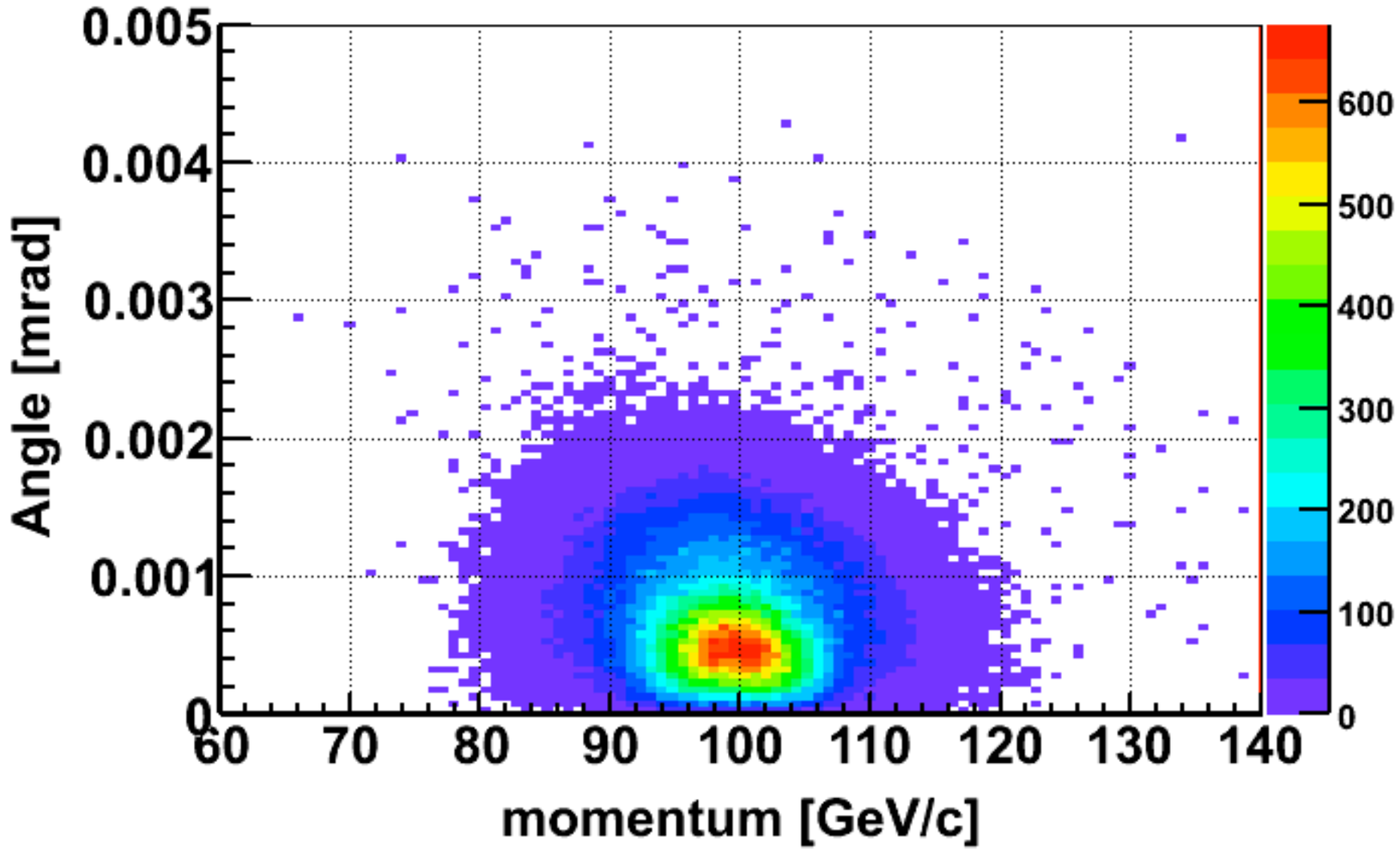
- Physics requirements
  - kinematic coverage, resolution
- Beam optimization
  - optics, aperture
  - special optics?: low emittance,larger β*...
- Detector optimization
  - Tracking: Material, geometry, location
- Trigger detector
  - segmented scintillator counters(?)
  - triggering
  - rejecting backgrounds using timing
- Full detector simulation
  - detector response, background
- On-going data taking in STAR diffractive program at RHIC bridging simulation and eRHIC

# Extra

# Tagging spectators in $^3$He

- Crucial for identifying processes with a neutron "target" (e+n) in e+$^3$He
  - Spectator neutron (<~3 mrad) can be measured by ZDC
  - Tagging spectator protons from $^3$He
    - Relying on separation from magnetic rigidity ($B_r$) changes
      $^3$He: p = 3/2:1
    - No need to reconstruct momentum but need clean identification:
      - position+directional measurement
- Can a common detector be utilized for tagging forward proton from DVCS and the spectator protons from $^3$He?

# Spectator protons in $^3$He




- Momentum smearing mainly due to Fermi motion + boost
- Angle <~3mrad (>99.9%)